REVISED DRAFT
GUIDELINES FOR GLOBAL POSITIONING SYSTEM UNITS
Revised and updated May 2007

STATE WATER RESOURCES CONTROL BOARD

Prepared by the Geographic Information System Subcommittee
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EXECUTIVE SUMMARY

The ability to accurately locate features and collect data relevant to California water resources is very important to the State and Regional Water Quality Control Boards. These features may include: underground storage tanks, landfills, water rights locations, sewage outfalls, monitoring locations, drinking water sources, etc. At the March 2000 GIS Subcommittee Meeting, meeting participants discussed the need for standards or guidelines for the purchase and use of Global Positioning System (GPS) units by State and Regional Water Quality Control Boards staff. The original GPS standards document was approved by the Information Technology Steering Committee September 12, 2000.

At the August 2006 GIS Subcommittee meeting it was decided that there was a need to revisit the GPS standards to address changes in technology cost and functionality as well as changing program needs. The purpose of this report is to offer guidance and assistance to staff who seek to use GPS receivers in their work and to maximize the usability, exchange, and archival of GPS data within the State and Regional Water Boards. Several Water Boards program applications such as GeoTracker and CIWQS have the need for parties to upload GPS information. Standards were established for GeoTracker in April 2005 that exceeded the original GPS standards document of 2000 and these are referenced in this paper.

1.0 INTRODUCTION

The Global Positioning System (GPS) is a rapidly changing system that not only consists of the core system operated by the Department of Defense, but also includes other systems designed by other agencies that are currently on-line or planned for future implementation. The changing nature of the system makes it difficult to create a guidance document with specific recommendations that will not become out-of-date as the GPS evolves. This guidance document uses performance standards to give the user a set of criteria that can assist in evaluating different GPS receivers, data loggers and data management software. As new features are added to the GPS, some of the current criteria will become obsolete and the addition of new criteria will be required.

1.1 Objectives
The purpose of these standards is to offer guidance and assistance to staff who seek to use GPS receivers in their work and to maximize the usability, exchange, and archival of GPS data within the State and Regional Water Boards.

1.2 What is GPS?
The Global Positioning System (GPS) was developed by the Department of Defense to be used in military operations that require accurate positional information. The system consists of three segments: the space segment, the control segment and the user segment.

The space segment consists of 24 satellites (21 active satellites plus 3 back-up satellites). As each satellite orbits the earth it broadcasts a continuous signal that contains data associated with the satellite's position and its clock time. The satellites' orbits are set in such a way that between five and eight satellites are visible from any point on earth at any time.

The control segment consists of multiple tracking systems located around the world and a master control center located on an Air Force base in Colorado. The control segment calculates orbital information and clock errors for each satellite and transmits this information to the satellite. This information is incorporated into the satellite's broadcast.

The final segment of the system is the user segment. It consists of the GPS receiver and the user. GPS receivers are capable of receiving data from the satellites and converting it into position, velocity and time (PVT) estimates. Signals from four satellites are required to calculate position in three dimensions accurately due to inherent clock error in the GPS receiver.

GPS can be used for surveying, mapping, navigation of cars, boats and planes, backcountry navigation and increased time accuracy using GPS time in lieu of private atomic clocks. Data from a GPS receiver can be incorporated into a Geographic Information System (GIS) and displayed along with other geographic information.

GPS calculates a position using distance measurements to the GPS satellites. Signals broadcast by the satellites enable the GPS receiver to measure the transit time of the signals and thereby determine the distance (range) between each satellite and the user. Using the measurement information, a minimum set of four simultaneous equations are solved with the receiver position (x, y, z) and the receiver clock offset (to account for the receiver's clock bias) as the four unknown variables. The accuracy of this solution is dependent on the errors inherent in the system.

Six classes of errors are encountered in GPS:

1. Ephemeris Data – Errors in the transmitted location of the satellite.
2. Satellite Clock – Errors in the transmitted clock data.
3. Ionosphere – Errors in the corrections of pseudorange (the calculated distance between the receiver and a satellite) caused by ionospheric effects.
4. Troposphere – Errors in the corrections of pseudorange caused by tropospheric effects.
5. Multipath – Errors caused by reflected signals entering the receiver antenna.
6. Receiver – Errors in the receiver's measurement of range caused by thermal noise, software accuracy and interchannel biases.

These errors generate horizontal positional errors on the order of 10-20 meters. This is a good approximation of the accuracy of autonomous, "uncorrected" GPS. To reduce the magnitude of these errors to less than 10 meters, differential GPS (DGPS) is used.

Prior to May 2, 2000, one of the major errors associated with autonomous GPS was Selective Availability, which the military introduced into the system in order to degrade the accuracy of GPS up to 100 meters. Selective Availability has been discontinued, thereby greatly enhancing the accuracy of uncorrected GPS. However while accuracies have increased they could still be of by more than 10 meters if the data is not post processed.

Other sources of error can originate in the control segment by human or computer error, in the user or in the equipment due to software or hardware problems/failures. These cannot be quantified, but can cause errors from 1 meter to hundreds of kilometers.

Geometric Dilution of Precision (GDOP) is a measure of error based on satellite and receiver geometry. As GDOP increases, GPS accuracy decreases. The greatest amount of error is present when the lines-of-sight between the user and 2 or more satellites approach parallel, or when all four satellites approach the same plane. GDOP includes both position and time error estimates. Other dilution of precision factors include: Position DOP (PDOP) which incorporates position (x, y, z) error estimates; Horizontal DOP (HDOP) which incorporates horizontal position (x, y) error components; Vertical DOP (VDOP) which incorporates vertical (z) error estimates; and Time DOP (TDOP) which incorporates time (t) error estimates.

Recent developments in GPS have expanded on the core GPS. The FAA has implemented the Wide Area Augmentation System (WAAS) that incorporates two geostationary satellites and 24 ground stations that allow DGPS to be used by aircraft anywhere in the United States. The geostationary satellites broadcast the corrections from the 24 ground stations, thereby avoiding the signal masking problem of ground stations. Proposals for the next generation of GPS satellites include additional civil frequencies that can be used to increase the accuracy of GPS.

Also, the U.S. Coast Guard, along with other agencies, is developing a Nationwide DGPS that will ultimately have dual terrestrial coverage throughout the contiguous 48 states and single coverage in Alaska, Hawaii and Puerto Rico. The National Geodetic Survey and other agencies are developing the Continuously Operating Reference Stations (CORS) that allows for potential sub-meter positional accuracy using DGPS. As of January 2007, there were 1154 stations in the CORS network, of which 109 are in California. CORS correction data is available free to the public for download via anonymous ftp or the World Wide Web at http://www.ngs.noaa.gov/CORS/

1.3 What is Differential Correction?

Differential GPS is used to improve autonomous GPS accuracy by removing some of the error discussed in the previous section. DGPS uses a reference receiver (base station) at a known location to remove errors associated with ephemeris, satellite clock, ionosphere and troposphere errors. The correction can occur in real-time or during a later "post-processing" step. The assumption with DGPS is that two receivers located in the same vicinity will experience the same amount of error for each satellite range calculation. It does not correct for multipath or receiver noise errors. There are two basic types of differential of differential GPS: Differential Code GPS that provides 1-10 meter accuracy and Differential Carrier GPS that provides sub-meter accuracy.

Differential Code GPS uses a single frequency (L1) receiver for receiving GPS satellite broadcast signals. Real-time differential code GPS requires a radio link to a base station that corrects for errors that are common to the base station and the GPS receiver. Post-processing corrects for the same errors that real-time DGPS corrects, but it involves performing the corrections at a later time using correction data generated by a base station. This data is usually available for download.

Differential Carrier GPS uses a dual frequency (L1 and L2) receiver for receiving GPS satellite broadcast signals. The L2 frequency allows the receiver to achieve sub-meter accuracy. The dual frequency configuration increases the cost of the receiver over that of a single frequency receiver.

2.0 GPS PERFORMANCE STANDARDS

2.1 GPS Accuracy

On May 1, 2000, the Federal government discontinued Selective Availability (SA). This action by the Federal government resulted in the increased accuracy of autonomous GPS positioning. However, ionospheric and other errors remain that may have to be corrected in order to maintain the desired level of positional accuracy. Discontinuing the use of SA improves the accuracy of GPS for civilian users from within 100 meters to within 10 to 20 meters

SWRCB and Regional Board programs should collect GPS data that is differentially corrected to achieve a positional accuracy of 1 to 5 meters or better (i.e. the location of a NPDES permitted facility or water rights point of diversion). The Underground Storage Tank program as of 2006 (Geotracker application) requires contractors to submit GPS data of tank locations to be collected using an approved GPS unit that has sub-meter accuracy.

http://www.waterboards.ca.gov/ust/cleanup/electronic_reporting/docs/GeoTrackerSurvey_XYZ_4_14_05.pdf

It is important that staff consider the full spectrum of potential applications for the GPS unit and purchase an appropriate system. In most cases, GPS systems that are capable of data logging and differential post-processing will be the optimal choice. In general most recreational grade receivers collect data in the NMEA format, which cannot be post-processed to achieve better accuracy in the office. Survey Grade GPS units currently have the ability to download and post-process data to achieve better accuracy.

2.2 GPS Satellite Differential Receiver

The GPS receiver is the most important piece of system hardware for obtaining spatial data.
It is recommended that the GPS receiver:

a. includes an integrated GPS and satellite differential antenna for the reception of differential GPS transmissions from marine radio beacon broadcasts using minimum shift keying (MSK) modulation;

b. includes an integrated GPS and satellite differential receiver;

c. be a C/A code receiver with twelve L1 band channels;

d. automatically identifies and avoids GPS satellites that are specified as "Unhealthy" by the Department of Defense;

e. allows the selection of satellite elevation masks (satellites below this mask are not used for position fixes), signal level masks (satellites below this signal level are not used in calculating a position), and Position Dilution of Precision (PDOP) masks. PDOP is an indicator of the quality of a GPS position and is calculated according to the geometry of the satellites in relation to the GPS antenna;

f. for units which require sub-meter accuracy, use carrier phase-processed differential correction data;

g. be able to transform coordinate system and unit values in the field.

2.3 GPS Processing Software

In addition to accurately locating positions, the GPS system should include software that allows for the simple processing of field data. Smooth data flow between the office and the field is key for productive fieldwork and getting the data into the geographic information system (GIS). The GPS software should include a batch processor that allows staff to easily perform the tasks of data download, differential correction, and export to an ESRI GIS system. It is recommended that the software should include:

a. Microsoft Windows-based office processing software that has mission planning, data import, data dictionary creation, differential correction, and data export capabilities;

b. the ability to transfer existing data files to the data collector for the purpose of updating existing positional and/or attribute information;

c. project management functions that permit individual subdirectories to be created within the project directory for base files, export files, and backup files.

d. the ability to differentially post-process GPS data;

e. the capability of either code or carrier phase post-processing;

f. processing engines that do not require that the base station and the rover use the same constellation of satellites for position fixing;

g. the ability to export files in dBase and delimited ASCII text format. It is highly recommended that the software have the capability to export data files to a supported ESRI GIS format, such as shapefiles;

h. good documentation, including instruction manuals, on-line help and technical support.

2.4 GPS Coordinate System Support

GPS data may be framed within several spatial reference systems. A coordinate system defines the northings and eastings used on local maps. A horizontal "datum" adopts a reference ellipsoid and locates geodetically surveyed points on that ellipsoid. The North American Datum (NAD 27 and NAD 83) is an adjustment of geodetic measurements that provides the horizontal reference for North America. The selection of a datum and the notation of the datum utilized are critical to the collection of quality GPS data. It is recommended that the office software should include:

a. the ability to display, edit, export, and import data in the local coordinate system datum;

b. the ability to configure the units of measurement and decimal degrees for

positions, angles, offsets, distances, lengths, and areas;

c. a choice of north reference: true north or magnetic north.

2.5 GPS Featuring

The GPS system should enable the user to define and collect features as points (e.g. wells, tanks), lines (e.g. streams, roads), or areas (e.g. landfills, site boundaries). A point feature is defined as the average of a series of positions. A line feature is defined as a sequence of positions. An area feature is defined as a sequence of positions that close to form a polygon.

The GPS system should also enable the user to create a data dictionary so that feature attribute data may also be collected. It is recommended that the processing software:

a. includes a data dictionary editor, which allows for the creation of a user-defined data dictionary.

b. allows features with attributes to be added, edited, or moved to a new place within the data dictionary.

2.6 GPS Datalogging

Datalogging is an important component of collecting GPS data. It is recommended that the GPS data unit have:

a. an internal protected RAM (~2 MB) that is capable of storing at least 8 hours of data (one field day);

b. an internal power source to allow operation when not connected to GPS receiver or other external power source.

2.7 Hardware Features

GPS hardware features should include:

a. option for backlight;

b. compact, a large, clear, graphical display with the ergonomic design with an alphanumeric keyboard and sensible key spacing;

c. a "Help" key;

d. batteries that are easily recharged and/or replaced.

2.8 Equipment Durability

In many cases, staff will be using GPS units in remote areas away from the office. Therefore, it is imperative that the GPS equipment be field worthy and dependable. The following are recommendations with regards to equipment durability:

a. Data collector should at a minimum meet IEC 529 IP54 specification for water and dust proofing (including rain/dust resistance);

b. The GPS receiver should be fully sealed, dustproof, waterproof, and shock resistant;

c. GPS units should have rapid screen response and a crisp display even in extreme working temperatures.

2.9 Difference between recreational and professional grade GPS

Below is a compilation of some differences between the recreational grade GPS and the professional grade GPS.

- Recreational units that support Satellite Based Augmentation Systems (SBAS) such as Way Area Augmentation System (WAAS) will not typically report which positions are SBAS-corrected and which are not. So even though the unit might report one position with 3-meter corrected accuracy, it might report the next with 15-meter accuracy. The user will not know.

- Most recreational receivers will only output basic metadata and do not include enough information to enable post-processing.

- Although some recreational GPS units can collect points, lines and polygons, such functionality tends to be very limited.

- Professional grade GPS units can synchronize collected features with features in a GIS data layer or database, thereby maintaining feature integrity

and obviating the need for data conversions.

- Professional grade GPS can store larger amounts of information and richer attribute schemes than recreational grade units, which can store only minimal attribute information.

3.0 DOCUMENTATION OF FIELD METHODS

3.1 Field Protocol Documentation

To ensure high quality GPS data, it is important to collect feature locations consistently and document field protocols. Field documentation should include (at a minimum) the following items:

a. GPS date and time;
b. GPS filename;
c. Feature identification;
d. Feature type (point, line, area);
e. Site description;
f. Street address (if available);
g. Site contact (if available);
h. GPS reference point;
i. Offset description (if necessary);
j. Datum utilized;
k. Type of GPS unit;
l. Field notes.

3.2 Sample Field GPS Protocols

The following are a few sample field protocols:

Wells
The centroid of the wellhead is utilized as the GPS reference point.

Underground Storage Tanks
The centroid of the tank fill pipe (exposed at the ground surface) is utilized as the GPS reference point.

Aboveground Storage Tanks
The centroid of the aboveground storage tank is utilized as the GPS reference point.

When it is impractical to position a GPS receiver directly over the GPS reference point, an offset may be used. Offsets use the distance and bearing to a feature to determine the feature's actual location. All offsets should be reported in the field notes.

4.0 DATA REPORTING STANDARDS

4.1 Coordinate Systems

The most common geodetic coordinate system is the degree-minute-second (DMS) system. Due to the spherical surface of the earth, however, the system is not constant: the length of a latitudinal degree diminishes as one moves closer to the poles. In order to ensure accuracy, locations must be accurately reported.

For ease of integration with Geographic Information System software, the preferred method for reporting latitudinal and longitudinal coordinates is Decimal Degrees (DD) in the following pattern:

DD: dd.dddddd

The formula for converting DMS to DD is as follows:

$$DD = d + (m/60) + (s/3600)$$

In California, all longitudinal coordinates will be negative. It is also essential that the datum be reported with the coordinates.

If necessary, coordinates may be reported in Degree-Minute-Seconds (DMS) according to the following pattern:

DMS: dd mm ss.s

where d = degree, m = minutes, s = seconds. However, this method is not preferred.

4.2 Accuracy

The number of significant digits following the decimal point determines the accuracy of a reported decimal degree location. Longitudinal (horizontal) accuracy varies according to distance from the equator. The following table

lists the precision in meters for the major parallels in California:

Positional accuracy in meters

Latitude	Decimal places		
	3	4	5
33N	93.2559	9.32559	.932559
34N	92.1847	9.21847	.921847
35N	91.0855	9.10855	.910855
36N	89.9585	8.99585	.899585
37N	88.8042	8.88042	.888042
38N	87.6228	8.76228	.876228
39N	86.4146	8.64146	.864146
40N	85.1802	8.51802	.851802
41N	83.9198	8.39198	.839198
42N	82.6339	8.26339	.826339

Latitudinal (north-south) accuracy is constant along the meridians:

3 decimal places	111.195 meters
4 decimal places	11.1195 meters
5 decimal places	1.11195 meters
6 decimal places	.111195 meters

For example, a coordinate reported as 35.005N 122.4486E has a latitudinal error of approximately 111 meters and a longitudinal error of approximately 9 meters.

5.0 WATERBOARDS PROGRAM AND LEGAL REQUIREMENTS

Several Water Boards program applications such as Geotracker and CIWQS require parties to upload GPS information. Standards were established for GeoTracker in April 2005 that exceeded the original GPS standards document of 2000:

California State Water Resources Control Board Geotracker Survey XYZ, Well Data, and Site Map Guidelines & Restrictions.< http://www.waterboards.ca.gov/ust/cleanup/electronic_reporting/docs/GeoTrackerSurvey_XYZ_4_14_05.pdf> April 2007

5.1 Legal Requirements

The SWRCB has received a legal opinion from the State of California – State and Consumer Services Agency on behalf of the California Board for Professional Engineers and Land Surveyors as to the use of licensed professionals for collection of Geotracker XY&Z data. In summary, the collection of information related to the exact location of groundwater wells, required by Title 12, California Code of Regulations §§2729-2729.1, constitutes "land surveying," as the term is defined in section 8726 of the Business and Profession Code and the collection of data is restricted to those who are licensed to practice land surveying in California.

Summary of California Board for Professional Engineers and Land Surveyors to SWRCB:

The collection of information related to the exact location of groundwater monitoring wells, required by Title 12,California Code of Regulations §§ 2729-2729.1, constitutes "land surveying," as the term is defined in section 8726 of the Business and Profession Code and requires a license issued by the Board unless an exemption from licensure applies. Among the statutory exemptions are the following:

1. • Civil engineers registered prior to January 1, 1982. (Bus. & Prof. Code §8731.)

2. • Registered geologists or others persons authorized to practice geology, such as licensed civil and petroleum engineers. (Geological exemption, Bus. & Prof. Code §§ 8727 and 7838.) Please note that licensed civil and petroleum engineers may only conduct such surveying work to the extent they are by education and/or experience fully competent and proficient. (Title 16, California Code of Regs. § 415).

3. • Certain federal officials and subordinates to appropriately licensed professionals may engage in land surveying activities without being licensed. (Bus. & Prof. 7836, 7837, 7838, 6739, 6740 and 8730.)

As a matter of history and policy, professional land surveyors may be in the best position to perform this work since the scope of practice of land surveying fundamentally relates to determining the location of fixed works.

5.2 Program Requirements

GPS requirements for Geotracker are located on the SWRCB web site:

<http://www.waterboards.ca.gov/ust/cleanup/electronic_reporting/docs/GeoTrackerSurvey_XYZ_4_14_05.pdf>

CIWQS NPDES permits currently does not have standards for GPS upload.

Water Rights currently do not have legal requirements for the precision of a survey location.

It is generally recommended that positional accuracies of 1 meter or better are needed for most permitting program needs.

Some programs do not necessarily need sub meter accuracy but would benefit from using professional GPS not recreational GPS

6.0 STAFF TRAINING

The efficient and effective use of GPS equipment requires that field teams and other interested staff receive adequate and proper training in GPS concepts and use. Complete training should consist of two elements: an introduction to GPS concepts and a hands-on tutorial of the use of the particular GPS unit.

6.1 Introduction to GPS
Prior to using a GPS unit in the field, staff should be familiar with the following concepts:

    a. What is the Global Positioning System;
    b. The difference between Differential and Non-differential GPS;
    c. Real-time vs. post-processed differential correction;
    d. GPS accuracy;
    e. Ephemeris;

    f. Geometric Dilution of Precision (GDOP);
    g. Signal-to-Noise Ratios (SNR);
    h. Datums, particularly WGS 1984, NAD 1927 and NAD 1983;
    i. Sources of GPS error, including:
        1. Satellite geometry,
        2. Atmospheric interference,
        3. Multipath ("ghosting") errors;
    j. The need for proper field documentation.
    k. ArcGIS

Instruction in these concepts may be provided by State or Regional Board staff, the World Wide Web, a local educational resource (such as a community college) or through a vendor.

A GPS tutorial is provided at:
http://www.trimble.com/gps/index.shtml

The listing of these this tutorial does not constitute an endorsement of the vendors' products.

GPS vendors sometimes include training as part of a purchase, especially for high-end models. State and Regional Board divisions considering the purchase of a GPS unit should inquire whether the vendor will include training as part of the purchase package.

6.2 Hands-on training
The components of hands-on training will vary depending upon the capabilities of the specific GPS unit involved. Relevant components of training include:

Pre-field methods
    a. Project planning;
    b. Setting the GPS date and time;
    c. Setting the default datum/coordinate system;
    d. Creation of electronic data

Field methods
    a. Establishing communication link;
    b. Setting of PDOP/SNR masks;
    c. Datalogging;
    d. Attribute entry;
    e. Field documentation.

Post-field methods
    a. Downloading of information from datalogger (if supported);
    b. Post-processing differential correction, including downloading of CORS data from NOAA;
    c. Error correction;
    d. Metadata creation;
    e. Export to GIS or CAD data format (if supported).

Whenever possible, training should include a "tutorial" project involving the collection of GPS coordinates for several "sample" sites and incorporating all of the elements listed above.

7.0 RECOMMENDATIONS

This guidance document proposes a middle ground solution for the acquisition of GPS equipment and software based on the assumption that less than 1 meter accuracy is required by some programs (UST) and for others 1-5 meter accuracy is sufficient for the geographic data needs of the State and Regional Water Quality Control Boards. This takes into consideration the initial expense of the equipment and the fact that the equipment must accommodate different, and unforeseen, uses. Some applications such as Geotracker have specific standards that are legal requirements of the program and this should be considered as part of the GPS purchase justification.
When purchasing GPS the issues in this document should be taken into consideration and if possible the attached checklists should be used.

7.1 GPS purchase checklist (For details see the full document)

Primary use of GPS _____

Other uses_____

Required field accuracy_____

GPS satellite differential receiver

❑ Includes an integrated GPS and satellite differential antenna.

❑ Includes an integrated GPS and satellite differential receiver.

❑ Is a C/A code receiver with twelve L1 band channels.

❑ Automatically identifies and does not use GPS satellites that are specified as "Unhealthy" by the Department of Defense.

❑ Allows selection of satellite elevation, signal level, and Position Dilution of Precision mask.

❑ For units that require **sub-meter** accuracy, the GPS unit should use carrier phase-processed differential correction data.

❑ The receiver should be able to transform coordinate system and unit values in the field.

Software

❑ Microsoft Windows-based office processing.

❑ The ability to transfer existing data files to the data collector for the purpose of updating existing positional and/or attribute information.

❑ The ability to differentially post-process GPS data.

❑ The capability of either code or carrier phase processing.

❑ Processing engines that do not require that the base station and the rover to use exactly the same constellation of satellites for position fixing.

❑ The ability to export to text (ASCII) format files.

❑ The ability to export to a supported ESRI GIS format such as a shapefile.

❑ Good documentation, including instruction manuals, on-line help and technical support.

GPS coordinate systems

❑ The ability to display, edit, export, and import data in the local coordinate system datum.

❑ The ability to configure the units of measurement and decimal degrees for positions, angles, offsets, distances, lengths, and areas.

❑ A choice of north reference: true north or magnetic north.

GPS featuring

❑ Includes a data dictionary editor.

❑ Allows features with attributes to be added, edited, or moved to a new place within the data dictionary.

GPS Data logging

❑ An internal protected RAM (~2 MB) that is capable of storing at least 8 hours of data.

❑ An internal power source.

Hardware Features

❑ A large, clear, graphical display with the option for backlight.

❑ Compact, ergonomic design with an alphanumeric keyboard and sensible key spacing.

❑ Batteries that are easily recharged and/or replaced.

Equipment Durability

❑ Data collector should meet IEC 529 IP54 or better for ruggedness and waterproofing.

- [ ] The GPS receiver should be fully sealed, dustproof, waterproof, and shock resistant.
- [ ] GPS units should have rapid screen response and a crisp display even in extreme working temperatures.

Field Protocol Documentation

To ensure high quality GPS data, it is important to collect feature locations consistently and document field protocols. Field documentation should include (at a minimum) the following items:

- GPS date and time
- GPS filename
- Feature identification
- Feature type (point, line, area)
- Site description
- Street address (if available)
- Site contact (if available)
- GPS reference point
- Offset description (if necessary)
- Datum utilized
- Type of GPS unit
- Field notes

Sample Field GPS Protocols

The following are a few sample field protocols:

- Wells - The centroid of the wellhead is utilized as the GPS reference point.
- Underground Storage Tanks - The centroid of the tank fill pipe (exposed at the ground surface) is utilized as the GPS reference point.
- Aboveground Storage Tanks - The centroid of the aboveground storage tank is utilized as the GPS reference point.

Coordinate Systems and Accuracy

- Decimal degrees is the recommended geodetic coordinate system format with 6 decimal places and the datum reported.

7.3 List of GPS Units Supported by SWRCB GIS Unit

Sub meter accuracy GPS unit models
Trimble GeoXT

1-3m accuracy GPS Unit Models
Trimble GeoXM

2-5m accuracy GPS Unit models
Trimble GeoExplorer 3 (no longer can be purchased)
Trimble Recon GPS XB
Trimble Recon GPS XC

Trimble Software
ArcPad with GPScorrect and GPS Analyst

Other GPS units not supported by SWRCB GIS unit may still be used by State and Regional Board programs not requiring support.

Recreational GPS with unknown positional accuracy (2-15m)

Garmin models
GPSMap76
GPSMap76S
GPSMap76C
GPSMap76Cx
GPSmap60
GPSmap60Csx

Freeware GPS software for Garmin units listed above is available from Minnesota Department of Natural Resources:
DNR Garmin Application 2007 <http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html> April 2007

7.4 Comparison of GPS Units

Unit name	GIS integration software: commercial or freeware	Recreation or survey grade	Accuracy	Differential correction	Data dictionary on the GPS unit	Displays other GIS data on the GPS unit	Output to GIS (shapefile)	Integration into GIS Enterprise SDE Geodatabase	Supported by DIT[4]	Meets Geotracker Tanks unit standard [5]	Cost of unit and software[6]
Trimble GeoXT	Commercial[1]	Survey	< 1m	Yes (post process)	Yes	Yes[1]	Yes	Yes[1]	**Yes**	**Yes**	$5700
Trimble GeoXM	Commercial[1]	Survey	1-3m	Yes (post process)	Yes	Yes[1]	Yes	Yes[1]	**Yes**	No	$3800
Trimble Recon GPS XB/XC	Commercial[1]	Survey	2-5m	Yes (post process)	Yes	Yes[1]	Yes	Yes[1]	**Yes**	No	$2400
Garmin GPSmap60/Cx/Csx	Freeware[2]	Recreation	2-15+[3]	No	No	No	Yes[7]	No	No	No	$250-480
Garmin GPSMap76/S/C/Cx	Freeware[2]	Recreation	2-15+[3]	No	No	No	Yes[7]	No	No	No	$200-480
Garmin eTrex/Legend/Vista	Freeware[2]	Recreation	2-15+[3]	No	No	No	Yes[7]	No	No	No	$250-500
Magellan eXplorist	n/a	Recreation	2-15+[3]	No	No	No	No	No	No	No	$100-400

[1] Trimble units integrate with GIS software using either ESRI ArcPad (with GPS correct and GPS analyst) or Trimble Terrasync software. ArcPad (with GPS correct and GPS analyst) are the SWRCB standard software for Trimble GPS units. Terrasync does not provide integration with the SWRCB enterprise data library or multiple GIS layer display.)

[2] Freeware GPS/GIS software for Garmin units is available from Minnesota Department of Natural Resources:
       DNR Garmin Application 2007 <http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html> April 2007

[3] Accuracies greater than 15 meters are achieved via Wide Area Augmentation System (WAAS) signals and apply to open space or marine environments.

[4] Trimble GPS units with ArcPad are the State Board standard. **GPS units not supported by SWRCB GIS unit may still be used by State and Regional Board programs not requiring support (with the exception of underground tanks and wells).**

[5] Tank or well locations **must** be collected according to **"**California State Water Resources Control Board GeoTracker Survey XYZ, Well Data, and Site Map Guidelines & Restrictions" < http://www.waterboards.ca.gov/ust/cleanup/electronic_reporting/docs/GeoTrackerSurvey_XYZ_4_14_05.pdf> April 2007.

[6] Prices based on May 2007 estimates. Actual cost depends on contract CMAS, MSA, taxes, shipping and other options.

[7] Additional GIS software required for shapefile creation and support.